

# Study of Seat for Reduction of Stress of Sitting with Consideration of Influence of Physical Characteristics

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## ABSTRACT

Targeting individuals with physical characteristics that make them prone to experience a stress associated with sitting, the research discussed in this paper studied postures and methods of support for the lumbar and pelvic areas that would reduce the stress experienced by vehicle occupants during long periods of driving. Test subjects were asked to sit in seats offering different levels of support. In addition to a subjective evaluation of the stress associated with sitting, physiological indicators were measured. A Visual Analog Scale was employed for the subjective evaluation. For the measurement of muscular stress, in addition to conventional electromyograms, muscles in the deep layer were studied using an ultrasonic diagnostic device. A spinal mouse was employed to measure the shapes of test subjects' spines. The results indicated that the provision of adequate support from the 3<sup>rd</sup> lumbar vertebra to the 3<sup>rd</sup> sacral vertebra reduces the stress associated with sitting even in individuals with physical characteristics that make them prone to experience a stress in the lower lumbar or shoulder area. In addition, it was found that reduction of the stress associated with sitting made it possible to control both retroversion of the pelvis and kyphosis of the lumbar area. It was also determined that individuals who experience a greater stress in the shoulder area are experiencing a stiffening of the muscles in the deep layer of the shoulders.

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## 1. Introduction

Prolonged periods of driving place a mental and physical stress on the occupants of a vehicle. The mental stress is due to the tension and anxiety produced by the road environment and by driving itself. The physical stress results from posture maintenance and pressure on the body. The muscles are used to maintain the body's posture, the nerves are compressed by sitting, and the flow of blood decreases. It is considered that these factors cause symptoms such as tension, numbness, and pain in each part of the body.

With regard to thinking concerning postural adjustments that can reduce the stress of sitting, proposals have included reducing the activity of the back muscles by inducing a state close to the neutral posture that occurs in weightlessness<sup>(1)</sup>, and reducing the pressure on the intervertebral discs by inducing an S-shaped curve in the spine<sup>(2)</sup>.

With regard to the method of maintaining the posture, proposals have included using the combined support of the lumbar area and the pelvis to reduce the sense of discomfort

in relation to the strength of support<sup>(3)</sup>, and using support from the 3<sup>rd</sup> lumbar vertebra to the 3<sup>rd</sup> sacral vertebra to control both pelvic retroversion and lumbar kyphosis<sup>(4)</sup>.

In addition, in order to address the reduction in blood flow, approaches have included changing the amount of support close to the 3<sup>rd</sup> and 4<sup>th</sup> lumbar vertebrae over time<sup>(5)</sup> and changing the way that the femurs are supported<sup>(6)</sup>.

At the same time, research has also been conducted on individual differences. For example, research has also shown that because there are individual differences in the length and the strength of bones and muscles, there are differences in the comfortable angle of the neck and the relative angle between the pelvis and the femurs when sitting<sup>(7)</sup>, and that individual differences in the curvature of the spinal column result in differences in the stress on the lower lumbar vertebrae and the shoulders when sitting<sup>(8)</sup>.

It can be expected that setting the sitting posture to suit the individual's physical characteristics will reduce the stress associated with sitting, but the posture and the method of support for the lumbar area and the pelvis, which are important for maintaining posture, are not well understood.

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Seeking to reduce the stress of sitting for a greater number of people, the research discussed in this paper referred to the results of previous research<sup>(8)</sup> and selected individuals whose physical characteristics would make them prone to stress when sitting, and studied the posture of and methods of support for their lumbar and pelvic areas.

## 2. Selection of Individuals Prone to Stress when Sitting

### 2.1. Method of Measurement of Shape of Spinal Column

The test subjects were 15 adult males gathered by in-house recruitment. The shape of the spinal columns of potential test subjects was measured in chairs with no backs. Subjects displaying physical characteristics that would make them prone to stress when sitting were selected. An easily operable spinal mouse manufactured by Index Ltd. was employed in the measurements. The test subjects were instructed to relax their back and abdomen, and to keep their heads facing forwards and their gaze level.

A spinal mouse makes it possible to measure the relative angle of each vertebra in the spinal column by moving the tracking wheel of the device from the head to the pelvis, measuring spinous processes from the 7<sup>th</sup> cervical vertebra to the 3<sup>rd</sup> sacral vertebra.

Figure 1 shows the definition of spine shape employed. ThSp indicates the degree of curvature of all of the thoracic vertebrae; this was the sum of the angles formed by contiguous vertebrae from the 7<sup>th</sup> cervical vertebra to the 12<sup>th</sup> thoracic vertebra. LSp indicates the degree of curvature of all of the lumbar vertebrae. This value was determined as the sum of the angles between contiguous vertebrae from the 12<sup>th</sup> thoracic vertebra to the 1<sup>st</sup> sacral vertebra. LLSp indicates the degree of curvature of the lower lumbar vertebrae, and was defined as the sum of the angles between contiguous vertebrae from the 3<sup>rd</sup> lumbar vertebra to the 1<sup>st</sup> sacral vertebra. L5-S1 indicates the degree of local flexion of the lower lumbar vertebrae, and was defined as the angle

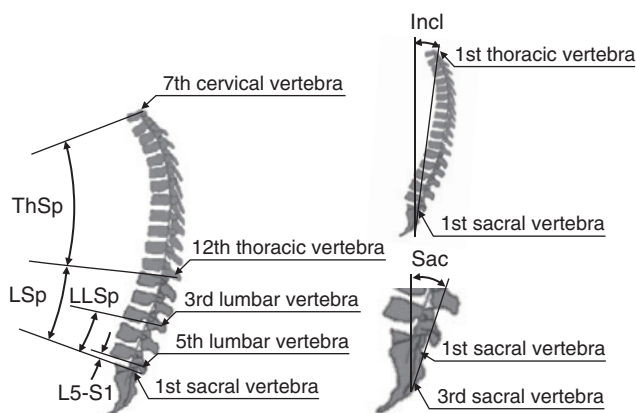


Fig. 1 Definition of spine shape

between the 5<sup>th</sup> lumbar and the 1<sup>st</sup> sacral vertebrae. The direction of kyphosis is shown as positive, and the direction of lordosis is shown as negative.

Incl indicates the degree of inclination of the upper body, and was defined as the angle between the line connecting the 1<sup>st</sup> thoracic and the 1<sup>st</sup> sacral vertebrae and a vertical line. Sac indicates the inclination of the pelvis, and was defined as the angle between the line connecting the 1<sup>st</sup> and 3<sup>rd</sup> sacral vertebrae and a vertical line. In relation to the vertical lines, backward inclination is defined as positive, and forward inclination is defined as negative.

This experiment was conducted with the approval of Honda's Bioethics Review Board. The purpose and details of the experiment and the rights of the test subjects were fully explained both orally and in writing by the personnel conducting the experiment prior to the experiment, and the consent of the test subjects was obtained in writing.

### 2.2. Method of Selection of Test Subjects

Previous research<sup>(8)</sup> showed that individuals with a greater degree of curvature of the lower lumbar area tended to be prone to feeling a stress on that area when sitting in a chair without a backrest. On the other hand, it has been reported that individuals with a rounded lower lumbar area and, in addition, a considerably rounded thoracic vertebrae tend to experience stress in their shoulders.

The research that forms the basis of this report, therefore, as Fig. 2 shows, defined individuals whose LLSp was the average value or higher when sitting on a chair with no backrest as individuals with physical characteristics that predispose them to experience stress in their lower lumbar area (termed the "lower lumbar group" below), and individuals whose LLSp was positive, and whose ThSp was average or higher as individuals with physical characteristics that predispose them to experience stress in their shoulders (termed the "shoulder group" below).

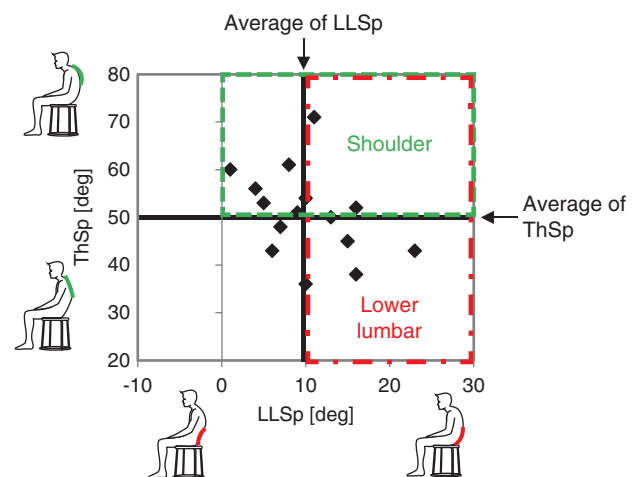


Fig. 2 Selection of test subjects prone to experiencing stress from sitting

### 3. Study of Method of Support for Reduction of Stress by Means of Subjective Evaluation

#### 3.1. Method of Measurement of Stress

In order to study methods of support able to reduce the stress of sitting on the lumbar area and the pelvis, the lower lumbar group and the shoulder group were asked to subjectively evaluate the stress of sitting in an experimental seat. The experimental seat is shown in Fig. 3. The seat had a simple structure in which urethane of a level of hardness that would not affect the sitting posture was mounted on an even frame. The center of the backrest was provided with a slit so as to help prevent interference with the measurement instrument.

As shown in Fig. 4, test subjects were seated respectively for 30 minutes in a state without rigid urethane inserted between the urethane and the frame from the 3<sup>rd</sup> lumbar to the 3<sup>rd</sup> sacral vertebrae (termed “without support” below) and with a 30 mm-thick sheet of rigid urethane positioned on the frame between their 3<sup>rd</sup> lumbar and 3<sup>rd</sup> sacral vertebrae (termed “with support” below).

In order to do away with the effect of the order of the seating types, order was randomized, and the subjects were initially seated without any stress.

In order to make the front and rear positions of the test subjects’ buttocks the same in relation to the seat for both test conditions, the position of the buttocks was standardized when the test subjects were deeply settled

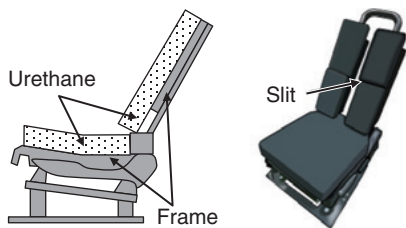


Fig. 3 Experimental seat

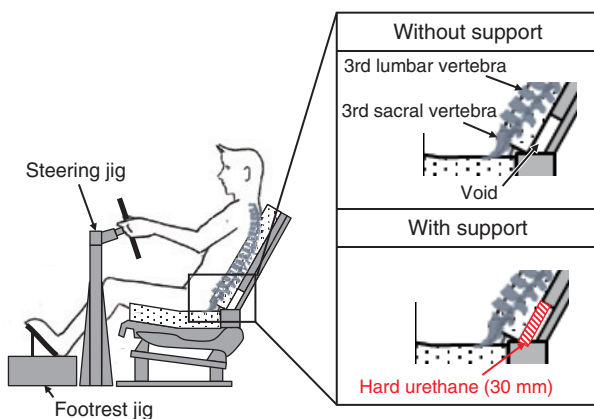


Fig. 4 Condition of experimental seat

in the seat with support, and the test subjects sat in the same position without support. In addition, the front and rear positions of the steering jig and the footrest jig were adjusted to make the angles of the elbows and the thighs the same for each test subject.

The test subjects were instructed to relax their backs and abdomens, hold the steering wheel with a light grip, turn their heads towards the front, and maintain a horizontal line of sight.

A Visual Analog Scale (VAS), which can be evaluated intuitively and is easily analyzed by means of analog quantity, was employed for the measurements. Using the VAS method, a 100 mm line is drawn, and the test subject draws a line on a scale expressing the current status when the left end is not felt at all and the right end is at the greatest possible strength that can be imagined.

#### 3.2. Method of Analyzing Stress

The distance between the left end of the VAS and the line drawn by the test subjects after sitting for 30 minutes was defined as the magnitude of stress.

In order to study the effect of the seat on the stress on the test subjects’ lower lumbar areas and shoulders, a one-way analysis of variance (repeated measurements) was conducted using support conditions as a parameter. The statistics package SPSS Statistics 24 (manufactured by IBM) was employed in the analysis. A significance level of 5% was employed.

#### 3.3. Analysis Results for Stress in Lower Lumbar Area

Figure 5 shows the results for subjective evaluation by the lower lumbar group when seated under unsupported and supported conditions.

The stress on the lower lumbar area from being seated was significantly lower in the supported condition than in the unsupported condition.

#### 3.4. Analysis Results for Stress in Shoulder Area

Figure 6 shows the results for subjective evaluation by the shoulder group when seated under unsupported and supported conditions.

The stress on the shoulder area from being seated was significantly lower in the supported condition than in the unsupported condition.

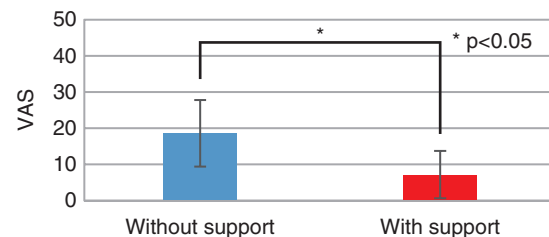


Fig. 5 Subjective evaluations for lower lumbar area

### 3.5. Summary of Methods of Support for Reducing Stress

It was found that the provision of adequate support from the 3<sup>rd</sup> lumbar to the 3<sup>rd</sup> sacral vertebrae reduced the stress associated with being seated, even in individuals with physical characteristics that made them prone to experiencing stress in their lower lumbar or shoulder areas.

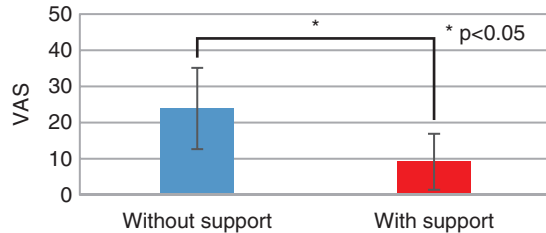


Fig. 6 Subjective evaluations for shoulder area

## 4. Investigation of Causes of Stress Associated with Sitting through Physiological Measurements

The stress associated with sitting described in Chapter 3 includes stress caused by maintaining the posture and stress caused by pressure on the body. The lower lumbar section of the back in which the stress was felt was positioned in the slit in the experimental seat, which meant that the seat tended not to compress the body.

In addition, the shoulders are positioned at the upper end of the experimental seat, and tend not to be compressed compared to the lumbar or pelvic areas. They therefore tend not to be compressed by the seat, and it was considered that the stress experienced in the tests was muscular fatigue due to maintaining the posture. Muscular stress was, therefore, evaluated using physiological indicators. The seating conditions were the same as described in Chapter 3.

### 4.1. Method of Measurement of Physiological Indicators

Electromyograms (EMG) are generally employed in order to evaluate muscular stress, and a NeXus electromyograph manufactured by KISSEI COMTEC was therefore employed for the evaluation in this research.

It is generally indicated that the accumulation of muscular stress results in stiffening of the muscular tissue. Given this, the stiffness of the test subjects' muscles was also evaluated in the research under discussion. Ultrasonic diagnostic equipment (a JS2 manufactured by Medicare) with an elastography function<sup>(9)</sup> making it possible to image the stiffness of the muscular tissue (muscular strain) was employed in the measurements.

In conducting measurements of muscular strain, it is necessary to press the probe of the ultrasonic diagnostic

equipment into the test subject's back. This means that measurements cannot be conducted while the test subject is sitting on the experimental seat. The test subjects were, therefore, asked to move to a nearby chair without a backrest before and after sitting in the experimental seat, and measurements were conducted there. To help ensure that they did not relax their muscles when they transferred to the separate seat, the test subjects were instructed not to move unnecessarily, and that they should flop into the chair and not raise their heads more than necessary.

Based on the structure of the muscles, it was considered that the stress associated with seating would occur symmetrically on both sides of the spine. The EMG and muscle strain were, therefore, measured at positions that were symmetrical in relation to the spine. The measurement positions in the height direction were intermediate between the 5<sup>th</sup> lumbar and 1<sup>st</sup> sacral vertebrae, where the stress on the lower lumbar area was experienced, and at the 1<sup>st</sup> thoracic vertebra, where the stress on the shoulder area is experienced (Fig. 7).

In order to observe changes in muscle strain, it is necessary to have a strain value that serves as a benchmark. Gel pads, whose strain values would not change during the measurements (Hydro Aid, manufactured by Nippon BXI, Inc.), were, therefore, placed on the surface of the test subjects' skin at the measurement positions, and the strain in the muscle tissue and that in the gel pads (the benchmark value) were measured simultaneously.

### 4.2. Method of Analysis of Measurement Results

In order to evaluate the stress on the muscles, the frequency of the electromyogram was analyzed, and the mean power frequency (MPF) was determined. Generally, the value of the MPF declines as muscular stress accumulates. In the research under discussion, the difference between MPF five minutes before the test subjects stopped sitting and five minutes directly after the subjects commenced sitting was compared for the different support conditions.

In addition, the muscle tissue strain value was divided by the gel pad strain value to give a muscle strain ratio, and the difference in the muscle strain ratios before and after sitting were compared for the different support conditions.

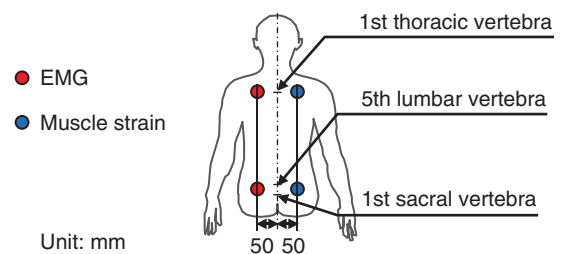


Fig. 7 Measurement points

As Fig. 8 shows, the muscles of the shoulder are layered. The shallow layer extends from 10-20 mm from the surface of the skin, and the deep layer from 20-30 mm. Muscle strain ratios were determined for each depth.

A one-way analysis of variance (repeated measurements) with the support conditions as parameters was performed in order to investigate the effect of the seat on MPF and muscle strain ratio. The significance level was set at 5%.

#### 4.3. Results of Analysis of Physiological Indicators Measured in Lower Lumbar Area

The electromyograms and muscle strain measured in the lower lumbar area for the lower lumbar group were compared for the different support conditions. As Fig. 9 shows, there was not a significant difference between the support conditions in MPF for the lower lumbar area.

Figure 10 shows the muscle strain ratio for the lower lumbar area. Under both sets of support conditions, the average value of the muscle strain ratio was negative, indicating that the muscle tissue tended to harden with sitting. However, no significant difference was observed between (a) the shallow layer and (b) the deep layer for the different support conditions.

#### 4.4. Results of Analysis of Physiological Indicators Measured in Shoulder Area

The electromyograms and muscle strain measured in the shoulder area for the shoulder group were compared for the different support conditions. As Fig. 11 shows, there was no significant difference between the support conditions in MPF for the shoulder area.

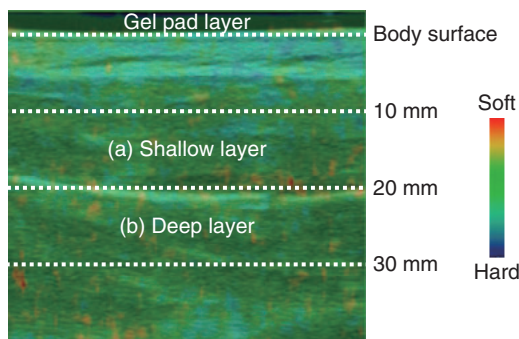


Fig. 8 Area for analysis of muscle strain

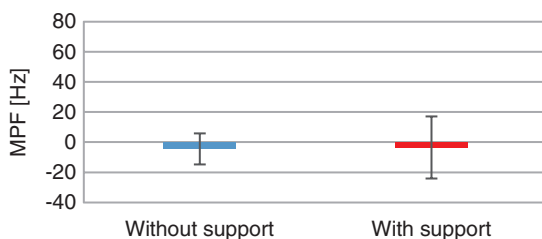
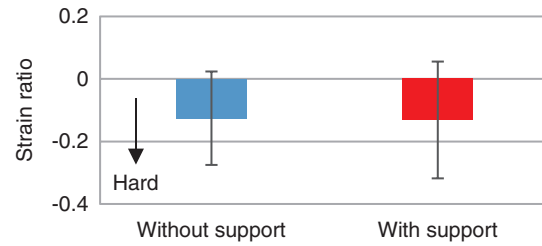
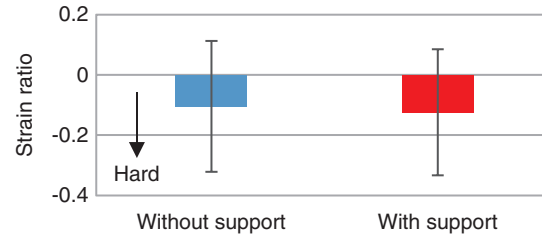


Fig. 9 EMG of lower lumbar area

In addition, as Fig. 12(a) shows, there was no significant difference in the muscle strain ratio between the different support conditions for the shallow layer of



(a) Shallow area



(b) Deep area

Fig. 10 Muscle strain ratio of lower lumbar area

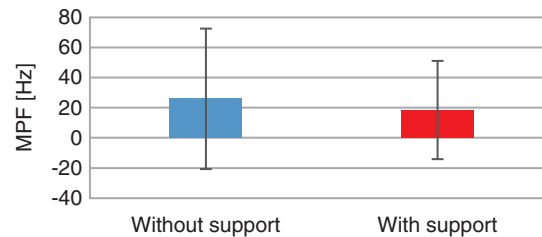
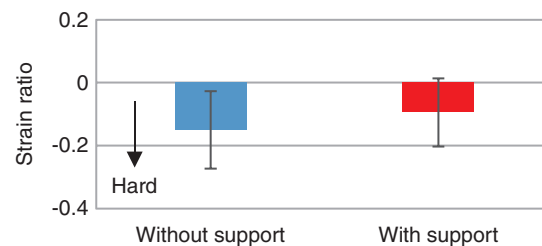
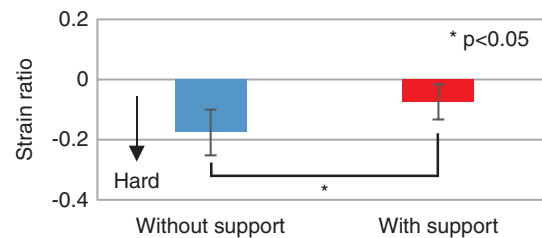


Fig. 11 EMG of shoulder area



(a) Shallow area



(b) Deep area

Fig. 12 Muscle strain ratio of shoulder area

the shoulder. However, as Fig. 12(b) shows, in the case of the deep layer, significance is lower for the muscle strain ratio without support. This indicates that the unsupported condition stiffened the muscles in the deep shoulder area.

#### 4.5. Considerations Regarding the Causes of Stress Associated with Sitting

The subjective evaluations indicated that the stress on the lower lumbar area was significantly greater under the unsupported condition, but no significant difference was shown between the conditions in terms of the indicator expressing muscular stress. It is, therefore, possible that muscular fatigue is not the cause of stress in the lower lumbar area, and will be necessary to adopt an approach other than muscular fatigue in order to investigate the cause of this stress.

At the same time, the stress on the shoulder area was significantly greater under the unsupported condition in the subjective evaluations, and the muscles in the deep layer of the shoulder were significantly stiffer. It was, therefore, considered that the stiffness of the deep layer affects the stress on the shoulder.

### 5. Study of Posture towards Reduction of Stress Associated with Sitting

#### 5.1. Method of Measurement of Posture

In order to study postures that reduce the stress associated with sitting, the shapes of the spines of the test subjects were measured using a spinal mouse when seated in the experimental seat in the unsupported condition, which was shown to produce the greatest stress, and in the supported condition, which was shown to produce the least stress in Chapter 3. The seating conditions were the same as described in Chapter 3, and the measurement positions were the same as described in Chapter 2.

#### 5.2. Method of Analysis of Measurement Results

A one-way analysis of variance (repeated measurements) with support conditions as parameters was conducted in order to study the effect of the seat on the shape of the spine when seated. The level of significance was set at 5%.

#### 5.3. Results of Analysis of Spine Shape

The shape of the spine when seated in the experimental seat was compared for the lower lumbar group and the shoulder group under the different support conditions.

As Fig. 13 shows, the results demonstrated that Sac, which indicates the inclination of the pelvis, LSp, which indicates lumbar curvature, and L5-S1, which indicates the flexion of the lower lumbar area, were all significantly lower for the supported condition.

In addition, as Fig. 14 shows, for the shoulder group, Sac and LSp were significantly lower for the supported condition.

This indicates that under the supported condition, both

pelvic retroversion and lumbar kyphosis can be controlled for the lower lumbar group and the shoulder group.

#### 5.4. Considerations in Relation to Posture in Order to Reduce Stress Associated with Sitting

In the subjective evaluation, the stress on the lower lumbar area was significantly lower, and the angle of retroversion of the pelvis and the flexion of the lower lumbar area resulting from lumbar kyphosis were significantly lower for the supported condition. It is considered, therefore, that it will be possible to reduce the stress on the lower lumbar area by controlling the retroversion of the pelvis and lumbar kyphosis.

In addition, in the subjective evaluation, the stress on the shoulders was significantly lower, and the angles of retroversion of the pelvis and kyphosis of the lumbar area were significantly lower for the supported condition.

Generally, when the pelvis is tilted backwards and the

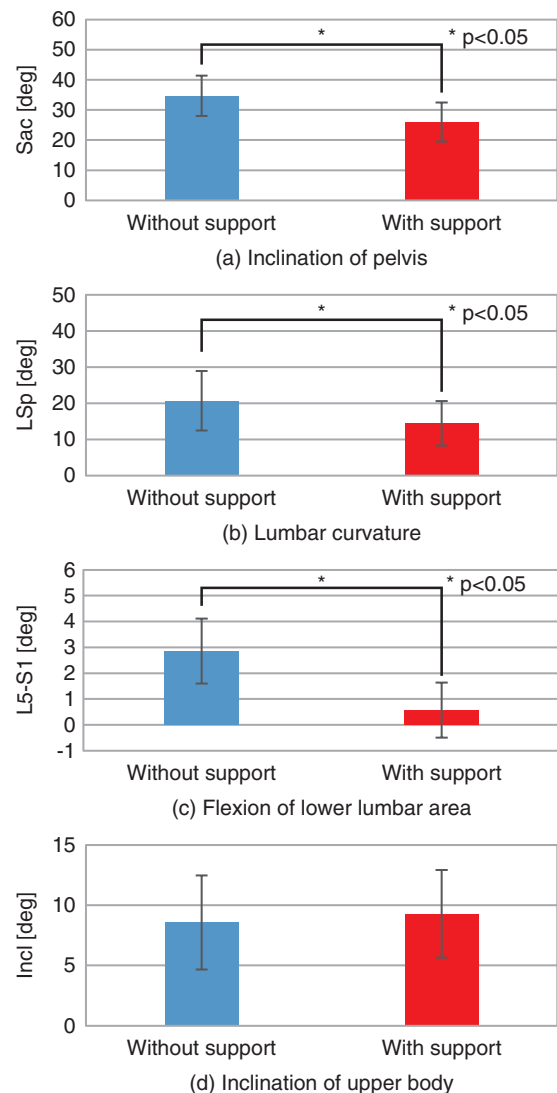


Fig. 13 Spine shape for lower lumbar group

lumbar area is in a state of kyphosis, the upper body is considered to be tilted forwards. In the present research, however, despite the fact that there was a difference in the angle of retroversion of the pelvis and the angle of kyphosis of the lumbar area due to the difference in support conditions, no difference was observed in the angle of the upper body.

Therefore, it is possible that the test subjects were utilizing muscular strength to help prevent their upper bodies from tilting forward in the unsupported condition, and it is considered that it was this that caused the muscles of the deep layer of the shoulder to harden.

This indicates that it will be possible to reduce the stress on the shoulders by controlling the retroversion of the pelvis and kyphosis of the lumbar area.

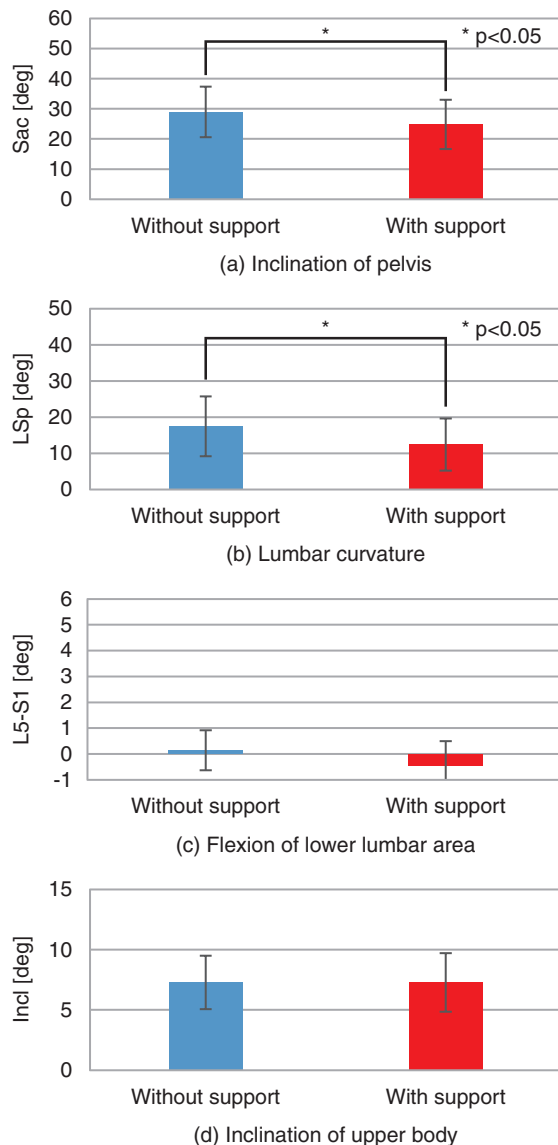


Fig. 14 Spine shape for shoulder group

## 6. Conclusion

Studying individuals possessing physical characteristics that make them prone to experience a stress when sitting, the research discussed in this paper studied postures and methods of support for the lumbar area and the pelvis that would reduce this stress. The results of the research are as follows.

- (1) Examination of a support method that would reduce the stress associated with sitting indicated that adequate support from the 3<sup>rd</sup> lumbar vertebra to the 3<sup>rd</sup> sacral vertebra reduces the stress associated with sitting even in individuals with physical characteristics that make them prone to experience a stress in their lower lumbar or shoulder areas.
- (2) Analysis of the causes of the stress associated with sitting based on measurement of muscle strain indicated that among individuals with physical characteristics that make them prone to experience the stress of sitting in their shoulders, the greater the stress, the greater the stiffening of the muscles in the deep layer of the shoulder. The use of ultrasound diagnostic equipment made it possible to evaluate the stress on the deep layer of the muscles of the shoulders, which had previously not been possible.
- (3) Among individuals with physical characteristics making them prone to experience stress in the lower lumbar or shoulder areas, a lower stress enabled control of both retroversion of the pelvis and kyphosis of the lumbar area.

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